§3. Measurement of Transmittance of the Optical Fibers Used for LHD Thomson Scattering Diagnostic

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In the LHD Thomson Scattering (TS) system, heavily obliquely backscattered light from an Nd:YAG laser beam along a major radius is collected and focused by a spherical mirror onto the end of the arrayed 200 optical fiber, each having core diameter of 2mm. The scattered light thus collected is transported 40 m distance from a harsh environment, where intense electromagnetic and neutron radiation are expected to be present, to a mild environment (diagnostic room) where sensitive photo detectors works reliably. In designing such TS system, one serious concern was the radiation-induced loss in transmittance of fibers to be exposed in the future DD experiments. If this loss is wavelength dependent, it will introduce a systematic error in the deduced electron temperature (Te) as well as in the electron density (ne). To avoid this problem, we paid an intense effort to obtain the optical fiber with a high radiation resistance. In 1994, we first asked three fiber makers to fabricate fibers with the highest radiation resistance applying their highest technologies. These fibers were exposed to 1 MR/h CO60 gamma ray for several hours while monitoring the transmittance in the visible-NIR region. The data, shown in Fig.1, compare the radiation-induced loss in the fibers made by the three makers. It was considered that the differences in the losses arise from the purity of glass ingot and the fiber-fabrication processes developed by each maker. The A-maker withdrew at this stage. Significant improvement was realized in a short period by the F- and the M-makers as shown in Fig. 2. We concluded that both the F No.2 type and the M No.4 type fibers had the highest radiation resistance attainable at that time. We purchased the M-No.4 type fibers via a competitive bidding. It should be noticed that these data were taken for fibers with core diameter ~200 μm. How the radiation-induced loss depends on the core diameter has not yet clearly understood.

More than 16 years has passed since the fibers were delivered. Although there is no documentation concerning the transmittance drop of a fiber placed in the normal environment, it may be worthwhile to re-measure the transmittance before the beginning of the planned DD experiment, which will serve as reference data base for studying how much radiation-induced loss occurs in the fibers exposed to the expected neutron fluence of up to 10^{13} n/cm^2. To this end, we asked the M-maker to measure the transmittance of 6 fibers sampled from 200. Table 1 shows the recently measured data together with those given at the delivery (1995-6-27). In considering the measurement accuracy, it can be concluded that no appreciable transmission loss has occurred in these past 16 years.

The recent high power ECH experiment realized high Te plasmas exceeding 10 keV, the measurement of which requires us to precisely examine the fiber transmittance at shorter wavelengths. By simply combing a tungsten-lump and a fiber-spectrometer (Ocean Photonics), we measured the fiber transmittance as a function of wavelength, as shown in Fig.3. It shows that the presently used fiber can be used for measuring the scattered light down to 500 nm.

FIBER#	2010-9-10					1995-6-27	
λ(nm)	**525**	**623**	**940**	**700**	**1100**	**700**	**1100**
171	89.5	93.9	96.9	97.2	97.0	96.9	98.1
143	87.1	90.9	97.7	97.4	99.1	96.0	98.6
187	89.3	92.6	96.9	99.4	99.1	96.2	98.0
155	92.0	95.8	99.9	97.1	99.1	98.5	98.8
170	90.6	96.9	95.3	97.1	96.8	97.4	98.3
174	90.6	98.1	96.2	97.2	95.1	96.8	98.2

Table 1. Transmittance of fibers measured on 2010-9-10 and 1995-6-27. Six fibers were sampled from 200.

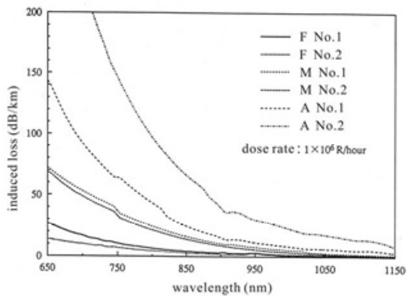

Fig. 1. Radiation-induced loss in fibers fabricated by three fiber makers. Fibers were exposed to 1MR Co60 X-ray.

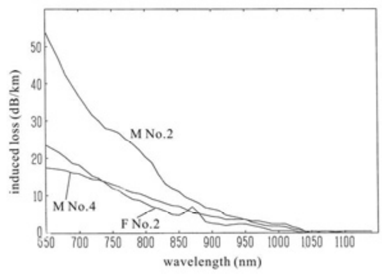

Fig. 2. Radiation-induced loss of the improved fibers.
. Fibers were exposed to 1MR Co60 X-ray.
Fibers of M-No4 type were delivered to NIFS.

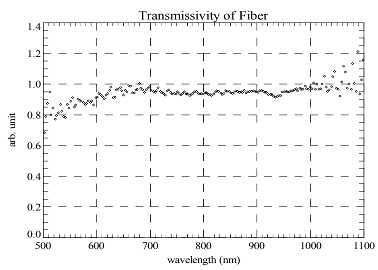

Fig. 3. Wavelength dependent transmittance of a current fiber.